INTERNATIONAL JOURNAL OF MECHANICAL ENGINEERING AND TECHNOLOGY (IJMET)

ISSN 0976 – 6340 (Print)
ISSN 0976 – 6359 (Online)
Volume 6, Issue 5, May (2015), pp. 64-71
© IAEME: www.iaeme.com/IJMET.asp
Journal Impact Factor (2015): 8.8293 (Calculated by GISI)
www.jifactor.com

IJMET

©IAEME

DESIGN ANALYSIS OF BUMPER BEAM SUBJECTED TO OFFSET IMPACT LOADING FOR AUTOMOTIVE APPLICATIONS

P. Sampath Rao

Professor, Mechanical Engineering Department,
Vijay Rural Eng. College, Nizamabad, T.S. INDIA.

S.Saikumar

M.Tech Student Mechanical Engineering Department,
Vijay Rural Eng. College, Nizamabad, T.S. INDIA

ABSTRACT

The bumper beam is fixed to front portion of the automobile structure and it is one of the primary component which undergoes damage and transfers the forces to the rest of the structure. Thus the modern bumper beam systems should play a key part in the safety concept of an automobile, ensuring that minimal accelerations are transferred to the passenger. Further the automotive producers are demanding for robust bumper beam systems showing good and reproducible impact behavior. The objectives of this study were to increase the physical understanding of the different phenomena taking place during the offset impact of an automotive bumper beam-longitudinal system as well as to validate a modeling procedure for the system's crash performance. In presented work the attempt has been made with Simulation of forming process for generating the FE-model of the bumper beam with required curvature. Finally the design and analysis bumper beam subjected to offset impact loading with different materials using FE-code ANSYS-LS DYNA and suggested the best material.

Keywords: Bumper Beam, FE-Model, Deflection and ANSYS-LS DYNA

1. INTRODUCTION

Fuel economy and emission gas regulations are the primary concerns in changing over to the light weight materials in automotive structures. Aluminium alloys are extensively used in various forms such as extrusions and castings due to its high strength to weight ratio and low density of aluminum compared to steel. Thus for modern cars aluminum alloys are employed in the front and

rear bumper beams, crash boxes, longitudinal-in the extruded form, also in other safety component such as side door impact beams, frames engine cradles, chassis, and suspension components. Although the use of the light weight materials helps in reducing fuel consumption and consequently lower carbon dioxide emissions, another stringent demand from the society is the passive safety obtained when employing light weight materials for automobile parts like bumper. Thin-walled tube-like structures have been extensively studied as energy absorbing components by various researchers and some of their opinions can be found in this literature.

The open literature available on bumper beam studies is vast and the majority of studies carried out into bumper beam design have been related to the US protection requirements. The structural performance of aluminum bumper beams is examined by **Sharp M.L. et.al [4],** from the standpoint of local damage (i.e. resistance to denting and cracking),with regard to low-velocity impact (8.3kmph).significant cost savings can be made of being able to damageability of proposed bumper beam designs from "blue prints". **Tang S.C**, **[5],** investigates computer modeling of bumper beam impact resistance and **Johnson W et.al [6]** studied a series of selected car bumper beams by quasi static loading at their mid-span, and showed that the assumption that a bumper beam could deform through 102mm before the body of the vehicle would become damaged was an over-estimate. However, the literature available on bumper beam systems connected to longitudinal is rather limited or non-existing. In this direction the researchers **Lademo O.-G [3]** and **Hanssen A.G et.al [7]** are studied the elastoplasticity and fracture for the material of aluminium alloys. **Barlat F., [10**] examine the Crystallographic texture, anisotropic yield surfaces and forming limits of sheet metals found that the yield surface shape has a tremendous effect on the predicted failure limits.

The objectives of this current study were to increase the physical understanding of the different phenomena taking place during the offset impact of an automotive bumper beam-longitudinal system as well as to validate a modeling procedure for the system's crash performance .For that choose different materials and select the best material for manufacturing the bumper beam longitudinal system from set of given materials. The objectives were achieved through FE code ANSYS-DYNA.

2. RESEARCH METHODOLOGY

2.1 Identification of Problem

The problem studied is outlined in Fig. 1 where a trolley, with a given initial velocity and mass, impacts the bumper beam-longitudinal system at 40% offset. The definition of 40% offset is taken as the distance from the impact point to the extreme left end of the bumper beam. At impact, the impact energy (kinetic energy) of the trolley is mainly absorbed in collapsing the bumper beam as well as the longitudinal at the impacted end, i.e. impacted longitudinal. While the non-impacted longitudinal experience only minor deformations.

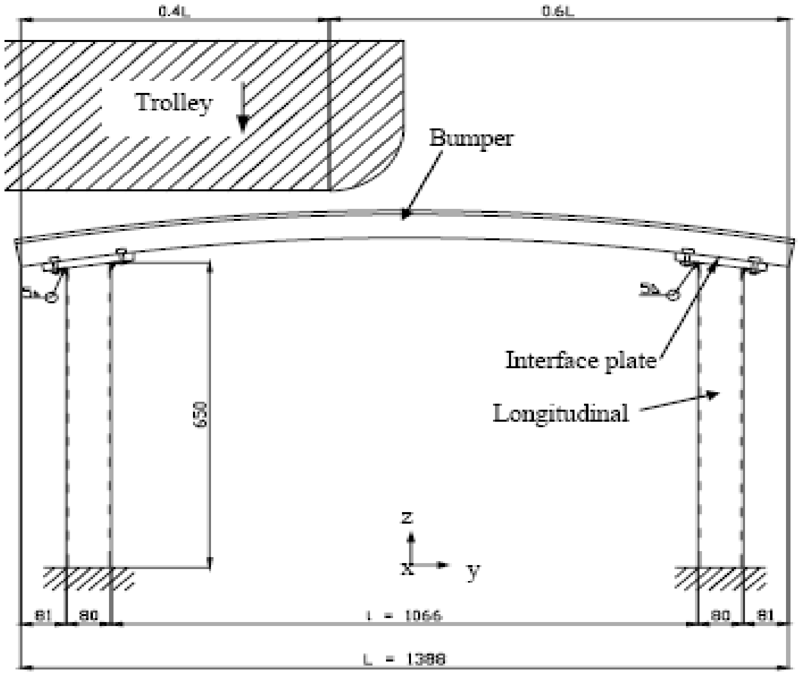

Fig. 1. Bumper beam-longitudinal system at 40% offset impact.

2.2 Modeling and design of bumper beam

In the design process and crash assessment of vehicles Finite Element Method (FEM) is an indispensable tool. It enables new design concepts to be evaluated where the optimum interaction between materials and structural forms can be studied. The value of such numerical analysis is strongly dependent on a precise description of the mechanical behavior of the material and also the application of enhanced material models. This means, however, that the code has to be validated against precision tests in the laboratory to ensure proper modeling of the member geometry, boundary conditions, material properties and fracture. Thus, in order to establish a reliable experimental database for the system in Figure 1 only few parameters were varied. The experimental database was used for the development and validation of modeling procedures for the crash performance of the bumper beam-longitudinal system with the use of the FE-code ANSYS-DYNA. The numerical model should be able to predict the collapse mode with a high level of certainty in order to ensure robust design. The modeling and design has been developed based on the assumption of ffset impact.

2.3 Bumper beam Material analysis

The bumper beam front part of automobile subjected to different loads in service while in impact, the selection of materials is important criteria, in this analysis chosen the material from material library that is aluminum alloy materials AA6060-T1, AA7003-T1 and AA7003-T79 with mechanical properties mentioned in following table 1

Table.1.Mechanical properties of aluminium alloy for Bumper beam

Property	AA6060-T1	AA7003-T1	AA7003-T79
E Modulus of elasticity, Mpa	69500	70000	70500
G Modulus of rigidity, Mpa	26100	26200	26100
ϑ Poisson ratio	0.3	0.29	0.31
Ultimate tensile strength, Mpa	150	150	155
Shear stress, Mpa	95	95	95

3. ANALYSIS, RESULTS AND DISCUSSION

The presented work is design and analysis of bumper beam member for automotive applications based on the topography optimization. In this investigation the analysis has been carried out for select the best material for manufacturing the bumper beam longitudinal system from set of given materials. The objective was achieved through FE code ANSYS-DYNA and results are presented in table.2

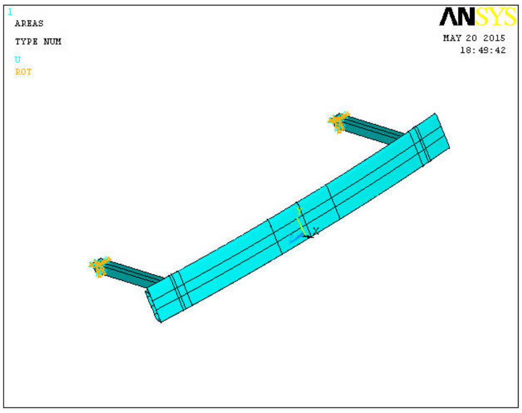

Fig.2: Geometric model of bumper beam longitudinal system with constraints

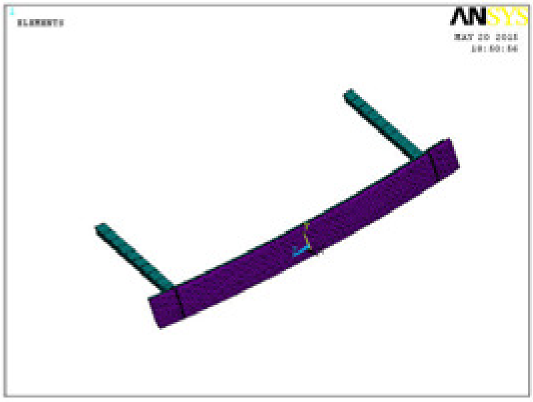

Fig.3: Finite element model of bumper beam longitudinal system

Efforts were taken in constructing the numerical model of the bumper beam as similar as possible to the reality. The bumper beam and all other components in the system were meshed in order to make a precise model.

The figures 4 to 7 are shows the deformed shapes of the bumper beam at different time intervals after impact for the material AA7003-T1.

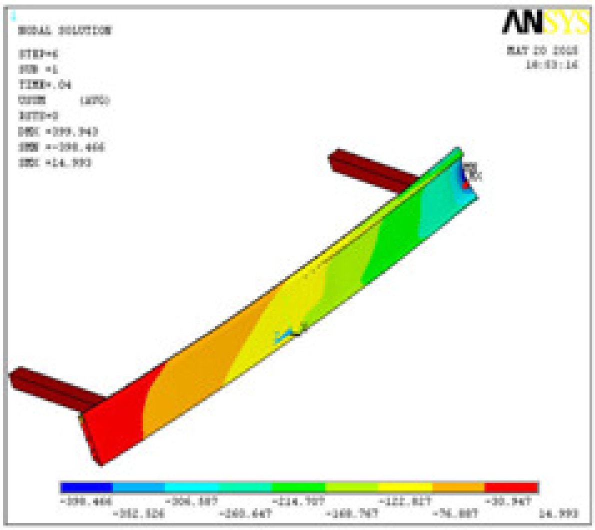

Fig.4: Deformed shape of bumper beam longitudinal system at 0.01 sec

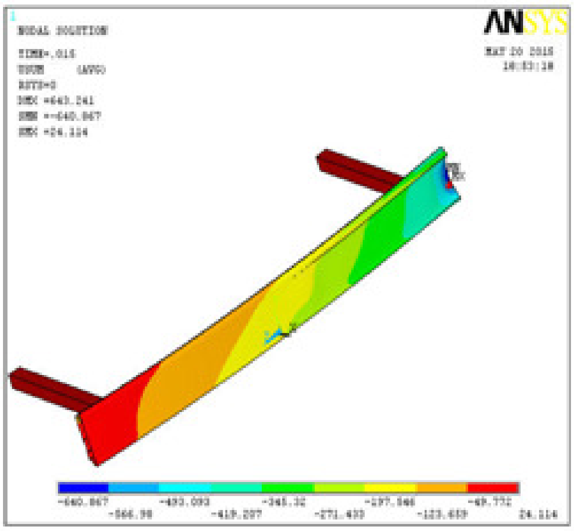

Fig.5: Deformed shape of bumper beam longitudinal system at 0.015 sec

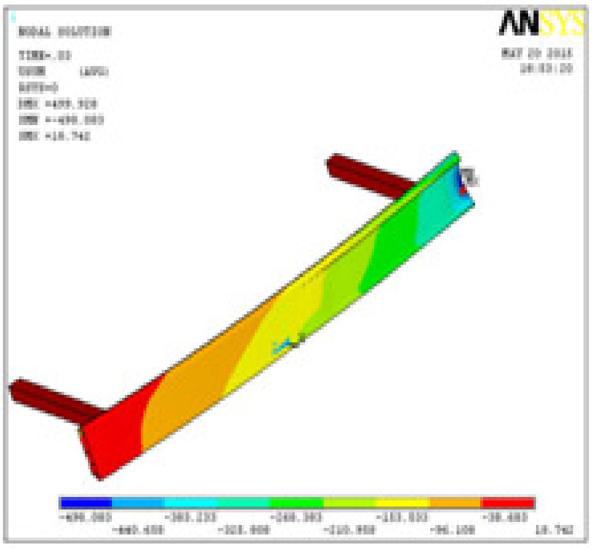

Fig.6: Deformed shape of bumper beam longitudinal system at 0.03 sec

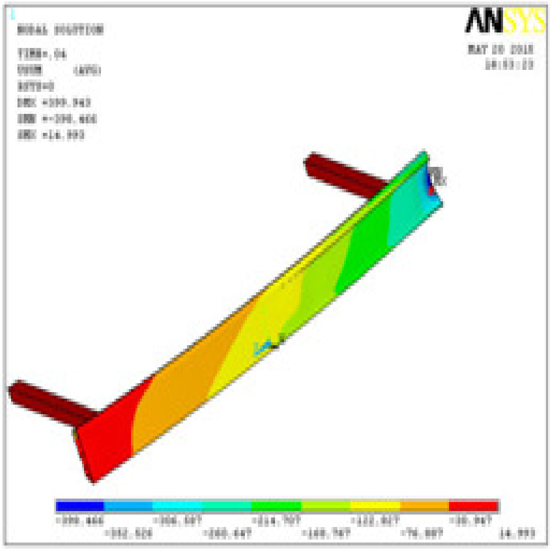

Fig.7: Deformed shape of bumper beam longitudinal system at 0.04 sec

The bumper beam longitudinal system shows maximum deformation at time t=0.015 sec i.e., when all the impact energy was absorbed. In the simulations the impact energy is converted to plastic work.

The figures 8 to, 11 are shows the deformed shapes of the bumper beam at different time intervals after impact for the material AA7003-T79.

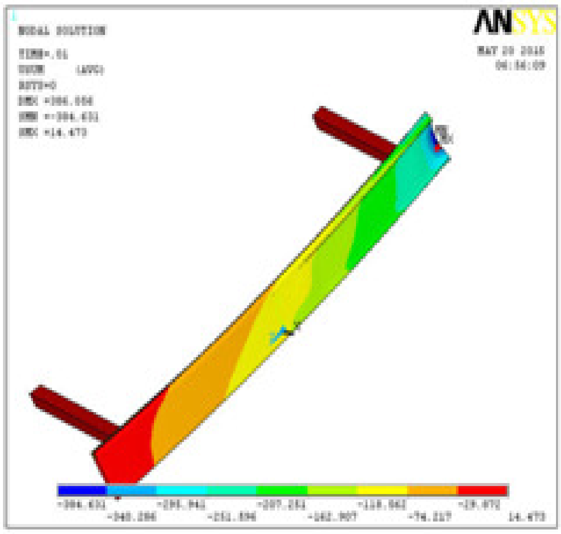

Fig.8: Deformed shape of bumper beam longitudinal system at 0.01 sec

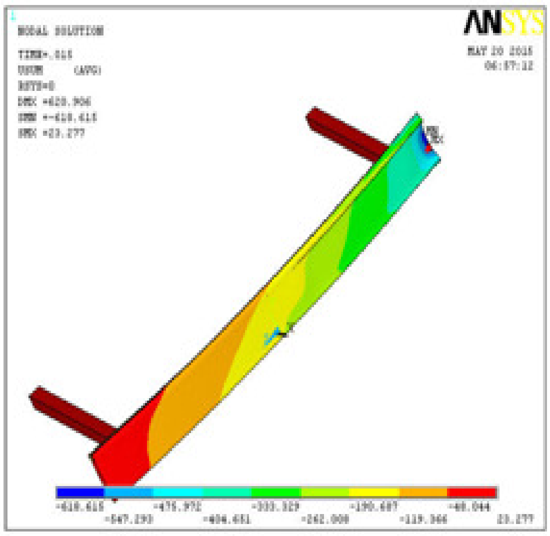

Fig.9: Deformed shape of bumper beam longitudinal system at 0.015 sec

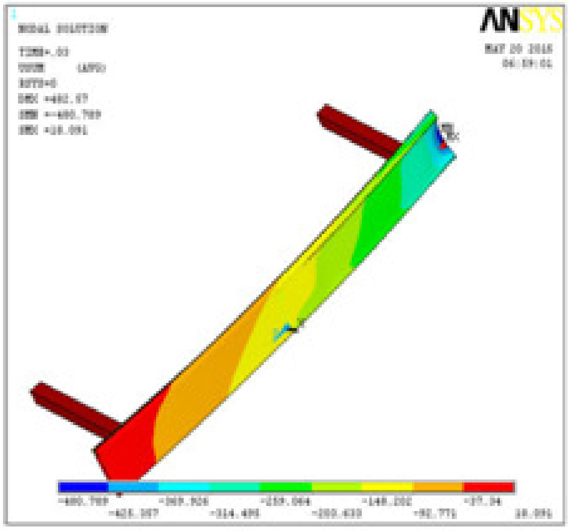

Fig.10: Deformed shape of bumper beam longitudinal system at 0.03 sec

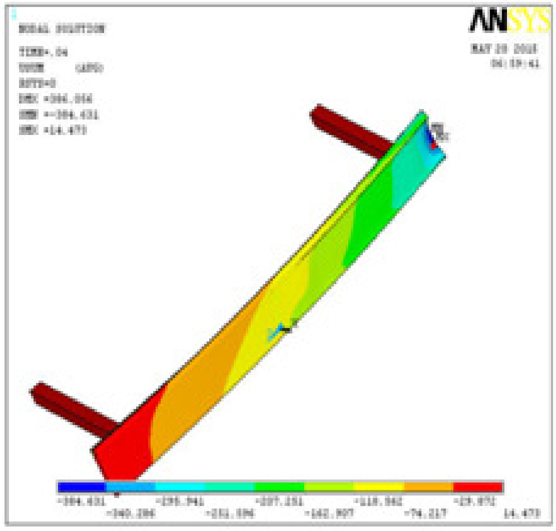

Fig.11: Deformed shape of bumper beam longitudinal system at 0.04 sec

The bumper beam longitudinal system shows maximum deformation at time t=0.015 sec i.e., when all the impact energy was absorbed. In the simulations the impact energy is converted to plastic work.

The figures 12 to 15 are shows the deformed shapes of the bumper beam at different time intervals after impact for the material AA6060-T1.

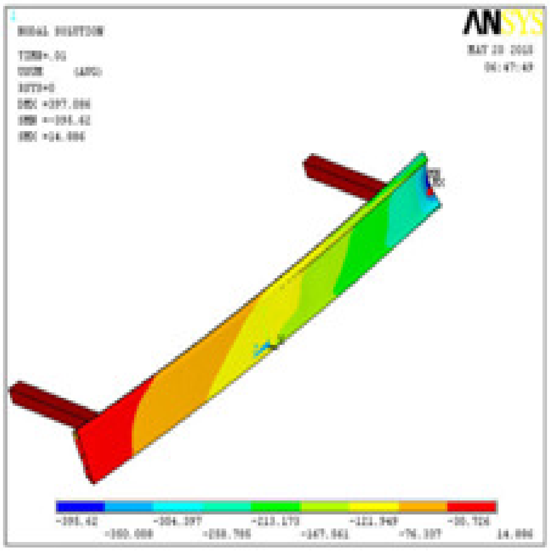

Fig.12: Deformed shape of bumper beam longitudinal system at 0.01 sec

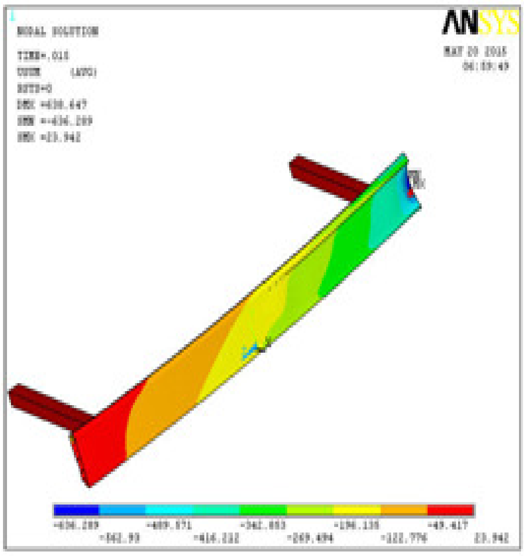

Fig.13: Deformed shape of bumper beam longitudinal system at 0.015 sec

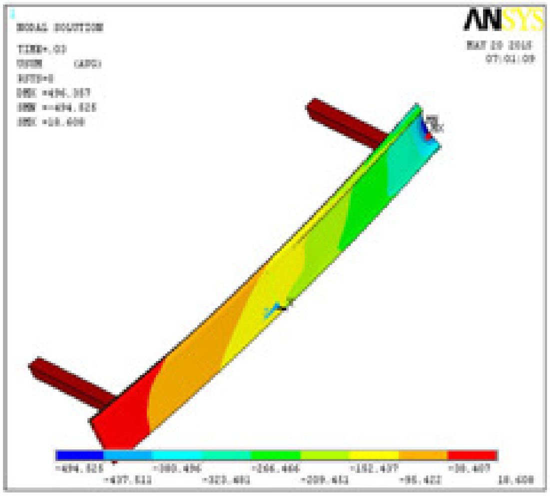

Fig.14: Deformed shape of bumper beam longitudinal system at 0.03 sec

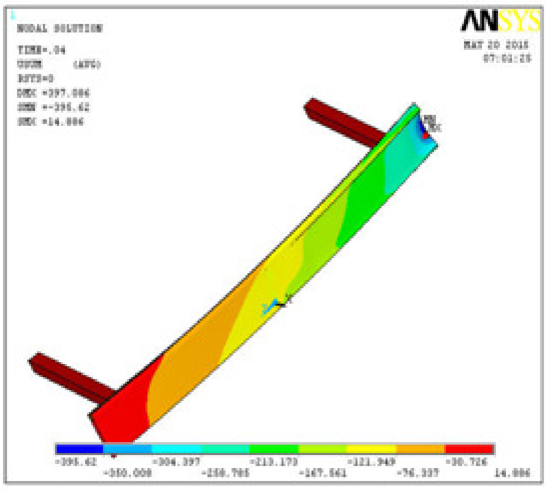

Fig.15: Deformed shape of bumper beam longitudinal system at 0.04 sec

The bumper beam longitudinal shows maximum deformation at time t=0.015 sec i.e., when all the impact energy was absorbed. In the simulations the impact energy is converted to plastic work

Table.2: Deflections of the bumper beam of different materials at different time intervals

Time(sec)	Dmx-AA7003(T1) in mm	Dmx-AA7003(T79) in mm	Dmx-AA6060(T1) in mm
0.01	399.463	386.248	397.458
0.015	643.241	620.145	636.144
0.02	402.215	386.778	399.151
0.03	499.588	482.887	496.225
0.04	399.943	386.492	396.559

From all the deformation shapes observed AA7003-T79 shows less deformation for the given load compared to other two alloys. From the table 2 it is clear that alloy AA7003-T79 is better compared to alloys AA6060-T1 and AA7003-T1 for manufacturing the bumper beam longitudinal system.

4. CONCLUSIONS

The presented research work is study the dynamic behavior of the bumper beam member by changing the different materials and structural properties. In this scenario FEA model has been generated through FE code ANSYS-DYNA for bumper beam member with the specified quality criteria and analyzed for the optimized results. From the analysis following conclusions are enumerated.

i. The AA7003-T79 shows high stiffness and plastic flow compared to AA7003-T1 and AA6060-T1.

ii. AA7003-T79 shows 3% less deformation compared to AA6060-T1 and 2.4% less deformation compared to AA7003-T1 for the given applied impact load.

iii. Velocities found on the bumper made of AA7003-T79 are less by 5% compared to AA6060-T1 and less by 15% compared to AA7003-T1, which implies that less energy is transferred to the passengers.

iv. Minimal Accelerations are transferred to the passengers in case of Bumper beam made with AA7003-T79.

REFERENCES

1. **Pugsley A and Macaulay M.A.,** Cars in collision-safe structures. New Scientist 78(596-598), (1978).
2. **Lademo O.-G., Berstad T., Hopperstad O.S. and Pedersen K.O**. A numerical tool for formability analysis of aluminium alloys. *Part I:* Theory. In: Proceedings of the 10th International Conference on Metal Forming. Edited by Kusiak, Hartley, Majta, Pillinger and Pietrzyk,Steel Grips, Suppl Metal Forming 2004, Kraków. (2004a).
3. **Lademo O.-G**. Engineering models of elastoplasticity and fracture for aluminium alloys. Dr.ing. Thesis, Department of Structual Engineering, Norwegian University of Science and Technology, Trondheim. ISBN 82-471-0367-2. (1999).
4. **Sharp M.L., Jombock J.R. and Shabel B.S,** Structural performance of aluminium bumpers. SAE Paper No 780140, 569-575, (1978).
5. **Tang S.C.,** Computer modeling of bumper impact resistance. SAE Paper No 790991, 3309-3319. (1979).
6. **Johnson W. and Walton A.C**., An experimental investigation of the energy dissipation of a number of car bumpers under quasi-static lateral loads. International Journal of Impact Engineering 1(3), 301-308. (1983).
7. **Hanssen A.G., Auestad T., Tryland T. and Langseth M**., The kicking machine: A device for impact testing of structural components. International Journal of Crashworthiness 8(4), 1-8, (2003a).
8. **Marciniak Z.,Duncan J.L. and Hu S.**J. Mechanics of Sheet Metal Forming. Butterworth-Heinemann, Oxford. ISBN 0-7506-5300-0,(2002).
9. **Dieter G.E**., Mechanical Metallurgy. McGraw-Hill, Singapore. (1988).
10. **Barlat F.,** Crystallographic texture, anisotropic yield surfaces and forming limits of sheet metals. Materials Science and Engineering 91, 55-72. (1987).
11. **Barlat F.,Maeda Y.,Chung K., Yanagawa M., Brem J.C., Hayashida Y.,Lege D.J., Matsui K., Murtha S.J., Hattori S.,Becker R.C and Makosey** S.Yield function development for aluminum alloy sheets. Journal of the Mechanics and Physics of Solids 45(11-12), 1727-1763, (1997b).
12. **Lemaitre J and Chaboche J.**L. Mechanics of Solid Materials. Cambridge University Press (1990).
13. **Aretz H,** Applications of *a* new plane stress yield function to orthotropic steel and aluminium sheet metals. Modelling and Simulation in Materials Science and Engineering 12,491-509, (2004).
14. **Yeh J.R., Summe T.L. and Seksaria D.C,** The development of an aluminum failure model for crashworthiness design. In: Crashworthiness, Occupant Protection and Biomechanics in Transportation Systems. Edited by Mahmood, Barbat and Baccouche, ASME, New York, (1999).
15. **ArkanJawdat Abassa, DhaferSadeq Al-Fatal,** “Experimental And Theoretical Study of The Influence of The Addition of Alumina Powder To 7020 Aluminum Alloy Foam On The Mechanical Behavior Under Impact Loading” International Journal of Mechanical Engineering & Technology (IJMET), Volume 3, Issue 3, 2012, pp. 412 - 428, ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.
16. **ArkanJawdat Abassa, DhaferSadeq Al-Fatal,** “The Effect of Dynamic Impact Loading With Combined Buckling Stresses on The Dynamic Surface Crack Propagation In Plates Subjected To Thermal Stresses” International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 6, 2013, pp. 122 - 137, ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.